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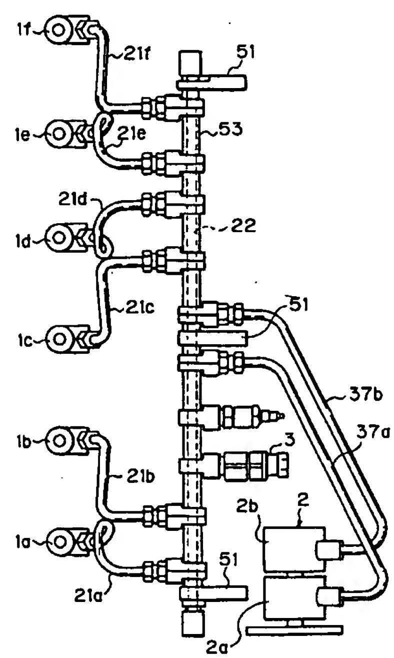
(54) A fuel injection device of an engine.

(57) A fuel injection device comprising a pair of fuel pumps (2a,2b), whereby fuel under high pressure discharged from the fuel pumps (2a,2b) is fed to the fuel reservoir (22) via the corresponding fuel feed pipes (37a,37b), fuel under high pressure in the fuel reservoir (22) is fed to the fuel injectors (1a-1f) via the corresponding fuel injection pipes (21a-21f), and fuel is discharged from the fuel pumps (2a,2b) in sychronization with the injection timing of the fuel injectors (1a-1f). The fuel feed pipes (37a,37b) have the same equivalent pipe length for the pressure wave propagation, and the fuel injection pipes (21a-21f) have the same equivalent pipe length for the pressure wave propagation.

Fig. 1



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BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a fuel injection device of an engine.

2. Description of the Related Art

In a known engine, fuel discharged from the fuel pump and under a high pressure is fed into a common fuel reservoir via a fuel feed pipe, and the fuel reservoir is connected to fuel injectors via corresponding fuel injection pipes. Thereafter, fuel is injected successively from the fuel injectors at each time the crankshaft has rotated through a predetermined crankangle. Unexamined Japanese Patent Publication No. 64-73166 discloses a fuel feed device suitable for such an engine, comprising a plurality of fuel pumps, and Unexamined Japanese Patent Publication No. 2-112665 discloses a fuel injector suitable for such an engine.

In this fuel injector, however, when the needle is opened, since the pressure of fuel in the fuel injector temporarily drops, an expansion wave is generated in the fuel injector, and this expansion wave is propagated in the fuel injection pipe and reaches the fuel reservoir. At this time, the expansion wave is reflected in the fuel reservoir and again propagated in the fuel injection pipe from the fuel reservoir toward the fuel injector, in the form of a pressure wave. This pressure wave is reflected at the fuel injector and is propagated in the fuel injection pipe toward the fuel reservoir, and thereafter, the pressure wave is reflected at the fuel reservoir and is propagated in the fuel injection pipe toward the fuel injector, in the form of an expansion wave, and accordingly, when the needle is opened, fluctuations occur in the pressure of fuel in the fuel injector. The period and amount of this pressure fluctuation depend on the diameter and length of the fuel injection pipe, and accordingly, if the diameter and length of the fuel injection pipes for each fuel injector are different from each other, the period and amount of pressure fluctuation generated in the fuel injector differ at each fuel injector, and thus a problem arises in that the amount of fuel injected by each fuel injector differs. The fuel injector disclosed in the abovementioned publication No. 2-112665, does not attempt to cope with this problem.

In the fuel feed device disclosed in the abovementioned publication No. 64-73166, fuel under a high pressure is successively discharged from the fuel pumps each time fuel is injected from the fuel injectors, but as mentioned before, when fuel under high pressure is discharged from the fuel pumps, a pressure wave is generated and propagated to the fuel reservoir via the corresponding fuel feed pipes. As a result, fluctuations occur in the pressure of fuel in the fuel reservoir, and this fluctuation of the pressure has an influence on the amount of fuel injected by the fuel injectors. If the diameters or lengths of the fuel feed pipes are different, the period and amount of the pressure fluctuation generated in the fuel reservoir by the pressure wave from the fuel pumps becomes irregular, and as a result, if an injection of fuel is carried out when the pressure of fuel in the fuel reservoir is high, the amount of the injected fuel becomes large, but if the injection of fuel is carried out when the pressure of fuel in the fuel reservoir is low, the amount of the injected fuel becomes Small. Accordingly, a problem arises in that the amount of injected fuel is different at each fuel injector. The fuel feed device disclosed in the above-mentioned publication No. 64-73166 also makes no attempt to cope with this problem.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a fuel injection device capable of preventing irregularities in the amount of injected fuel.

According to the present invention, there is provided a fuel injection device of an engine, comprising: a plurality of fuel injectors successively injecting fuel at each revolution of a crankshaft through a substantially fixed crankangle; a plurality of fuel pumps successively discharging fuel at each revolution of the crankshaft through the substantially fixed crankangle; a fuel reservoir common to all of the fuel injectors and fuel pumps; a plurality of fuel injection pipes connecting the corresponding fuel injectors to the fuel reservoir and having the same equivalent pipe length for the pressure wave Propagation; and a plurality of fuel feed pipes connecting the corresponding fuel pumps to the fuel reservoir and having the same equivalent pipe length for the pressure wave propagation.

The present invention may be more fully understood from the description of a preferred embodiment of the invention set forth below, together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

Fig. 1 is a plan view of the fuel injection device;

Fig. 2 is a side view of a portion of the Diesel engine;

Fig. 3 is a time chart illustrating the fuel injection time and the fuel discharge time of the fuel pumps; and

Fig. 4 is a schematic view of the fuel injector

and the fuel pump.

DESCRIPTION OF A PREFERRED EMBODIMENT

Figure 4 schematically illustrates a fuel injector 1 and a fuel pump 2.

Referring to Fig. 4, the fuel injector 1 comprises a needle 11 for controlling the opening of a nozzle opening 10. A back pressure chamber 12 is formed on the top face of the needle 11, and a pressure control chamber 13 is formed above the back pressure chamber 12. A check valve 14, permitting only an inflow of fuel to the back pressure chamber 12 from the pressure control chamber 13, is arranged between the back pressure chamber 12 and the pressure control chamber 13, and a restricted opening 15 is formed in the central portion of the check valve 14. The pressure control chamber 13 is selectively connected to an atmospheric pressure passage 18 or a fuel inlet 19 by a control valve 17 driven by a solenoid 16. The fuel inlet 19 and a fuel passage 20 connected to the nozzle opening 10 are connected to a fuel reservoir 22 via a fuel injection pipe 21.

When the pressure control chamber 13 is disconnected from the atmospheric pressure passage 18 by the control valve 17, as illustrated in Fig. 4, fuel under a high pressure in the fuel reservoir 22 is fed into the fuel passage 20, and into the back pressure chamber 12 via the fuel inlet 19, the interior of the control valve 17, the pressure control chamber 13, and the check valve 14. At this time the needle 11 closes the nozzle opening 10, due to the pressure of fuel acting on the top face of the needle 11.

When the solenoid 16 is energized, whereby the control valve 17 is moved upward, the pressure control chamber 13 is disconnected from the fuel inlet 19 and connected to the atmospheric pressure passage 18. At this time, fuel in the back pressure chamber 12 gradually flows out into the atmospheric pressure passage 18 via the restricted opening 15 and the pressure control chamber 13, and as a result, since the pressure of fuel in the back pressure chamber 12 gradually drops, the needle 11 gradually moves upward, and thus the injection of fuel is started. When the solenoid 16 is deenergized, the pressure control chamber 13 is disconnected from the atmospheric pressure passage 18 by the control valve 17, and fuel is fed to the back pressure chamber 12 via the check valve 14, and as a result, the injection of fuel is stopped.

The fuel pump 2 comprises a plunger 30 and a pressure chamber 31 defined by the top face of the needle 30. A cam 32 driven by the engine is arranged beneath the plunger 30, and a roller 32 rolling on the cam 32 is rotatably mounted on the lower end portion of the plunger 30. Accordingly, when the cam 32 rotates, the plunger 30 is caused to move up and down. A fuel feed port 34 is open to the lower interior of the pressure chamber 31, and the upper interior of the pressure chamber 31 is connected to the fuel reservoir 22 via a check valve 36 and a fuel feed pipe 37. A control valve 39 driven by a solenoid 38 is arranged on the top face of the pressure chamber 31, and the pressure chamber 31 is connected to a fuel discharge passage 40 via the control valve 39.

The cam 32 is rotated at a speed half that of the rotating speed of the crankshaft of the engine, and since the cam 32 has three projecting portions as illustrated in Fig. 4, the plunger 30 is caused to move upward at each revolution through a 240 crankangle of the crankshaft. When the plunger 30 is in the lower position, the fuel feed port 34 is open to the pressure chamber 31, and at this time, fuel is fed into the pressure chamber 31 from the fuel feed port 34.

When the upward movement of the plunger 30 is started, since the control valve 39 is open, fuel in the pressure chamber 31 is discharged into the fuel discharge passage 40, without being pressurized. When the solenoid 38 is energized, whereby the control valve 39 is closed, fuel in the pressure chamber 31 is pressurized as the plunger 30 moves upward. The fuel thus pressurized is fed into the fuel reservoir 22 via the check valve 36 and the fuel feed pipe 37.

As illustrated in Fig. 4, a pressure sensor 3 for detecting the pressure of fuel in the fuel reservoir 22 is attached to the fuel reservoir 22. This pressure sensor 3, an engine speed sensor 4 for detecting the engine speed, and a load sensor 5 for detecting the depression of the accelerator pedal are connected to a control unit 6. The solenoid 16 of the fuel injector 1 is controlled by signals output from the control unit 6 so that the needle 11 opens the nozzle opening 10 for a fixed time, regardless of the engine speed and the engine load. Accordingly, the amount of fuel injected by the fuel injector 1 is controlled by controlling the pressure of fuel in the fuel reservoir 22. The target pressure of fuel in the fuel reservoir is stored in advance as a function of the engine load and the engine load, and the solenoid 38 of the fuel pump 2 is controlled by signals output from the control unit 6 so that the pressure of fuel in the fuel reservoir 22, which pressure is detected by the pressure sensor 3, becomes equal to the target pressure. Broadly speaking, the target pressure of fuel in the fuel reservoir 22 becomes high as the engine load becomes high.

Figures 1 and 2 illustrate the fuel injectors and the fuel pump actually mounted on a Diesel engine 50. As illustrated in Figs. 1 and 2, the fuel reservoir 22 is formed in a common rail 53 supported by an

intake pipe 52 via a stay 51. Further, in the embodiment illustrated in Figs. 1 and 2, the Diesel engine 50 has six cylinders, and fuel injectors 1a, 1b, 1c, 1d, 1e, 1f are provided for each cylinder. These fuel injectors 1a, 1b, 1c, 1d, 1e, 1f are connected to the fuel reservoir 22 via corresponding fuel injection pipes 21a, 21b, 21c, 21d, 21e, 21f.

The fuel pump 2 comprises a first fuel pump 2a and a second fuel pump 2b connected to the fuel reservoir 22 via the corresponding fuel feed pipes 37a and 37b. Both the first fuel pump 2a and the second fuel pump 2b have the construction illustrated in Fig. 4, but the phase of the cam 32 of the first fuel pump 2a is deviated from the phase of the cam 32 of the second fuel pump 2b by 60 degrees, i.e., a 120° crankangle. Accordingly, fuel is discharged alternately from the first fuel pump 2a and the second fuel pump 2b. This procedure will be now described with reference to Figure 3.

As illustrated in Fig. 3, the fuel injection order of the Diesel engine illustrated in Figs. 1 and 2 is 1-5-3-6-4, and the cam 32 of the first fuel pump 2a is arranged so that the cam lift reaches a maximam height at the completion of an injection to every other injection cylinder #1, #3, #2, and the cam 32 of the second fuel pump 2b is arranged so that the cam lift reaches a maximum height at the completion of an injection to the remaining every other injection cylinder #5, #6, #4. Also, as mentioned above, the control valve 39 of the fuel pumps 2a, 2b is closed shortly before the cam lift reaches the maximum height, and the control valve 39 remains closed until the cam lift reaches the maximum height. When the control valve 39 remains closed, fuel is discharged from the fuel pumps 2a, 2b, and accordingly, fuel is discharged alternately from the fuel pumps 2a, 2b at each revolution of the crankshaft through a fixed crankangle, i.e., at each revolution of the crankshaft through a 120° crankangle in the embodiment illustrated in Figs. 1 and 2. In addition, as can be seen from Fig. 3, fuel is discharged from the fuel pumps 2a, 2b in synchronization with the injection timing.

As mentioned above, when the needles 11 of the fuel injectors 1a, 1b, 1c, 1d, 1e, 1f are opened; an expansion wave or pressure wave is proparated in the fuel injection pipes 21a, 21b, 21c, 21d, 21e, 21f. The time taken by the expansion wave or the pressure wave to propagate from one end of the fuel injection pipes 21a to 21f to the other end thereof, and the attenuating ratio of the expansion wave or the pressure wave, depend on the length, the diameter and the bends in the fuel injection pipes 21a to 21f. In this case, if the length of pipes in which the propagating time and attenuating ratio of the expansion wave or the pressure wave become the same is defined as an equivalent pipe length, all of the fuel injection pipes 21a, 21b, 21c, 21d, 21e, 21f have the same equivalent pipe length.

Where the pressure of fuel in the fuel reservoir 22 is constant, if all of the fuel injection pipes 21a to 21f have the same equivalent pipe length, the period and amount of fluctuations of pressure generated in the fuel injectors 1a to 1f become the same for all of the fuel injectors 1a to 1f, and as a result, the amount of fuel injected by the fuel injectors 1a to 1f becomes the same.

In the embodiment illustrated in Fig. 1, all of the fuel injection pipes 21a to 21f have the same length and the same diameter, but the bends in the fuel injection pipes 21a, 21d, 21e are different from those in the fuel injection pipes 21b, 21c, 21f. From the point of view that the equivalent pipe lengths of all of the fuel injection pipes 21a to 21f can be easily made the same, preferably all of the fuel injection pipes 21a to 21f are formed such that they have the same bends therein.

Similarly, the fuel feed pipes 37a and 37b have the same equivalent pipe length, and when fuel is discharged from the fuel pumps 2a, 2b, the pressure wave is propagated in the fuel feed pipes 37a, 37b. Nevertheless, since the fuel feed pipes 37a and 37b have the same equivalent pipe length, fluctuations of the pressure in the same amount are produced in the fuel reservoir 22 for a time which is the same as the time of the discharge operations alternately carried out by the fuel pumps 2a, 2b. Accordingly, as illustrated in Fig. 3, the fluctuations of pressure in the same amount are produced in the fuel reservoir 22 in synchronization with the fuel injection timing of the fuel injectors 1a to 1f. In this case, where the cam 32 is arranged so that the height of the maximum cam lift is different from that of the maximum cam lift illustrated in Fig. 3, the fluctuations of pressure in the same amount are produced in the fuel reservoir 22 at a crankangle distanced from the fuel injection timing of the fuel injectors 1a to 1f by the same crankangle. Accordingly, the fluctuations of pressure in the fuel reservoir 22 have the same influence on the pressure of fuel in the fuel injectors 1a to 1f, and thus the amount of fuel injected by the fuel injectors 1a to 1f becomes the same. Note that, as can be seen from Fig. 1, in the embodiment illustrated in Fig. 1, the fuel feed pipes 37a, 37b not only have the same equivalent pipe length, but also have the same length, the same diameter and the same shape. Further, where the fluctuations of pressure, caused by the discharge operations of the fuel pumps 2a, 2b, are produced in the fuel reservoir 22 in synchronization with the injection timing of the fuel injectors 1a to 1f as illustrated in Fig. 3, the peak pressure of the fluctuating pressure in the fuel reservoir 22 is cancelled by the expansion wave

propagated in the fuel injection pipes 21a to 21f, and thus an advantage is obtained in that the fluctuations of pressure produced in the fuel injectors 1a to 1f can be weakened.

Furthermore, in the embodiment illustrated in Fig. 1, the pressure drop of fuel between the fuel reservoir 22 and the fuel pumps 2a, 2b is substantially equal to the pressure drop between the fuel reservoir 22 and the fuel injectors 1a to 1f.

Although the invention has been described by reference to a specific embodiment chosen for purposes of illustration, it should be apparent that numerous modifications could be made thereto by those skilled in the art without departing from the basic concept and scope of the invention.

A fuel injection device comprising a pair of fuel pumps, whereby fuel under high pressure discharged from the fuel pumps is fed to the fuel reservoir via the corresponding fuel feed pipes, fuel under high pressure in the fuel reservoir is fed to the fuel injectors via the corresponding fuel injection pipes, and fuel is discharged from the fuel pumps in sychronization with the injection timing of the fuel injectors. The fuel feed pipes have the same equivalent pipe length for the pressure wave propagation, and the fuel injection pipes have the same equivalent pipe length for the pressure wave propagation.

Claims

1. A fuel injection device of an engine, comprising:

   a plurality of fuel injectors successively injecting fuel at each revolution of a crankshaft through a substantially fixed crankangle;

   a plurality of fuel pumps successively discharging fuel at each revolution of the crankshaft through said substantially fixed crankangle;

   a fuel reservoir common to all of said fuel injectors and said fuel pumps;

   a plurality of fuel injection pipes connecting said corresponding fuel injectors to said fuel reservoir and having tile same equivalent pipe length for the pressure wave propagation; and

   a plurality of fuel feed pipes connecting said corresponding fuel pumps to said fuel reservoir and having the same equivalent pipe length for the pressure wave propagation.

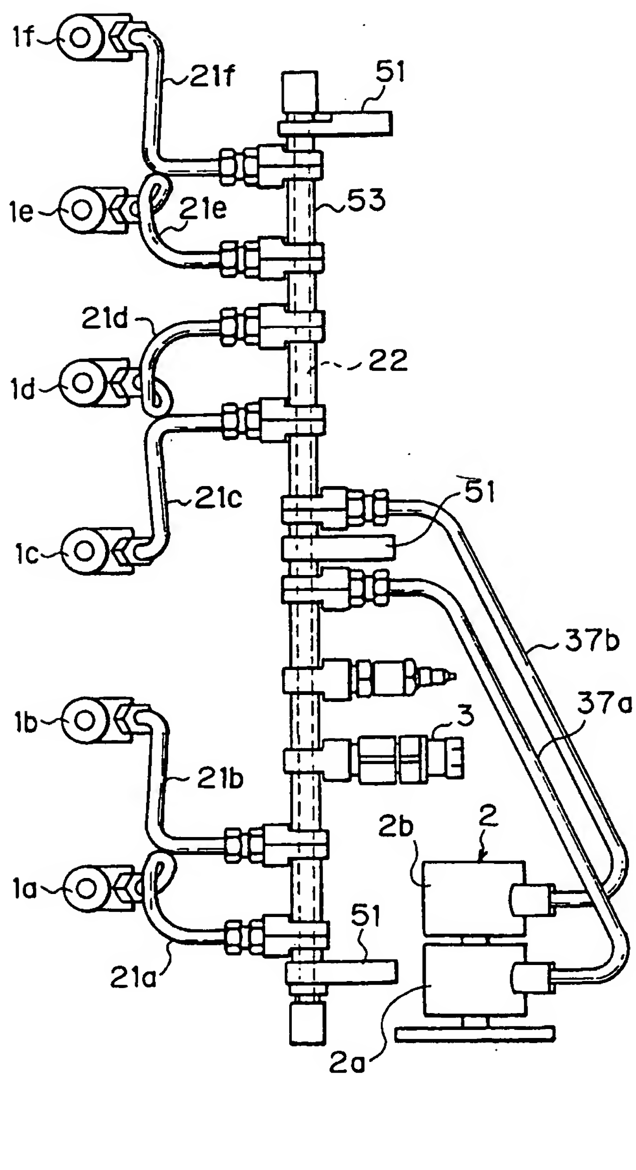
2. A fuel injection device according to claim 1, wherein the injection timing of said fuel injectors is synchronized with the discharge operations of said fuel pumps.

3. A fuel injection device according to claim 1, wherein said fuel injection pipes have the same length and the same diameter.

4. A fuel injection device according to claim 1, wherein said fuel feed pipes have the same length and the same diameter.

5. A fuel injection device according to claim 4, wherein said fuel feed pipes have the same shape.

FIg. 1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21a
2a

F/g. 2

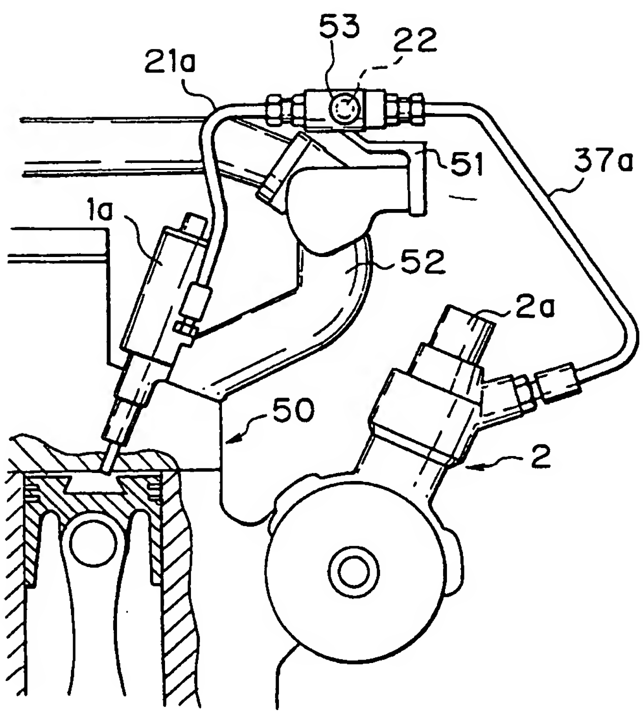

Fig. 3

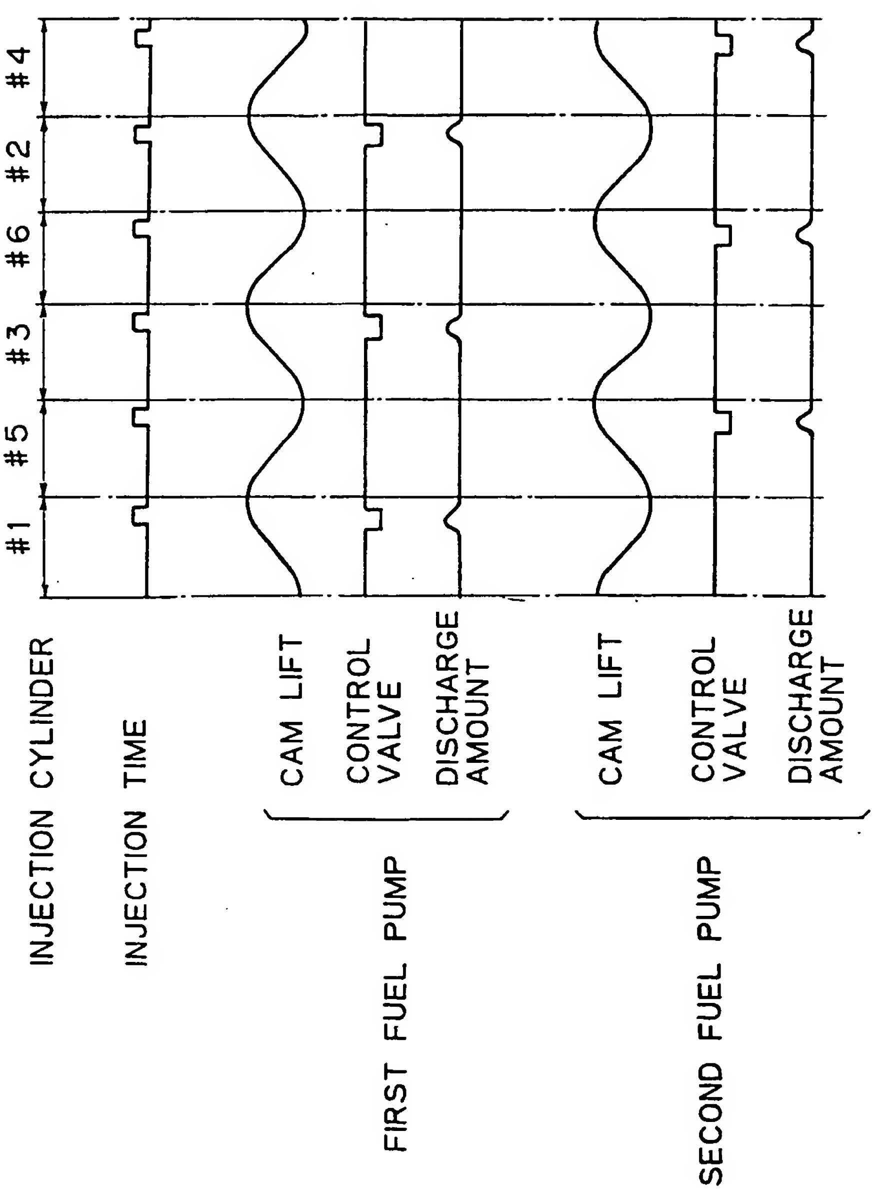
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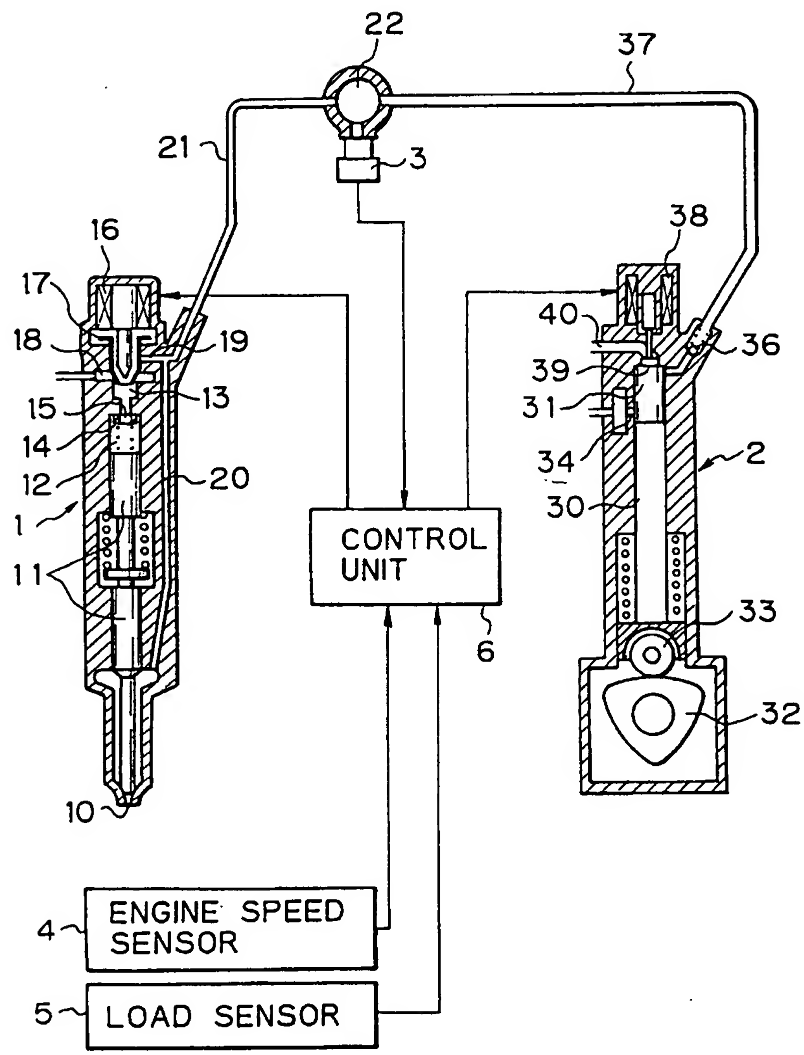
FIg. 4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CONTROL UNIT
11
33
6
32
10
4
ENGINE SPEED SENSOR
5
LOAD SENSOR

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 10 5042

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	FR-A-1 162 601 (BESSIERE) * page 1, right column, last paragraph - page 2, right column, paragraph 4; figure * ---	1	F02M55/02 F02M59/36 F02M55/04
A	EP-A-0 174 261 (UNITED TECHNOLOGIES) * page 7, line 5 - page 8, line 28 * * page 10, line 5 - page 13, line 5 * * page 16, line 21 - page 17, line 9; figures 1,2 * ---	1-5	
A	FR-A-2 548 279 (DAIMLER-BENZ) * abstract; figure 1 * ---	1,3-5	
D,A	EP-A-0 307 947 (NIPPONDENSO) * abstract; figure 2 * ---	1	
A	FR-A-2 341 752 (JOHNSON) -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			F02M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	25 MAY 1992	SIDERIS MARIOS

CATEGORY OF CITED DOCUMENTS

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